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CONCRETE DETERIORATION

by

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FOREWORD

The 50th Annual Convention of the National Sand and Gravel Association (NSGA) and the 36th Annual Convention of the National Ready Mixed Concrete Association (NRMCA) were held in Chicago, Illinois, 6-10 February 1966. A total of 17,500 persons were in attendance.

This paper was prepared for and presented at a joint engineering session of the two associations on 10 February. It was submitted to the Office, Chief of Engineers and approved for presentation and publication. It will be reproduced and distributed by the NSGA and NRMCA to their members. The paper was prepared under the direction of Mr. Thomas B. Kennedy, Chief, Concrete Division.

Colonel John R. Oswalt, Jr., CE, was Director of the Waterways Experiment Station during the preparation of this paper. Mr. J. B. Tiffany was Technical Director.

Concrete Deterioration*

by
Bryant Mather**

On a previous occasion I had the honor of addressing a joint session of the Annual Convention of the National Sand and Gravel Association and the National Ready Mixed Concrete Association. At that time, in New Orleans in 19[illegible], my topic was "The Mineralogical Properties of Aggregates and Their Significance." In the remarks I made then, I suggested that every person connected with either of your associations is necessarily a petrographer, [illegible] if you write about rocks. I also suggested that it was advantageous [illegible] each of you to know what rocks and minerals make up the aggregates you process, sell, and use but that you should not expect that mere knowledge of their names will solve all the problems you encounter with these various particles of rocks and minerals.

Today the subject of my remarks is "Concrete Deterioration," and particularly deterioration of concrete in service that is caused by forces other than externally applied loads. This is a part of the problems that you encounter [illegible] the use of the rocks and mineral particles that comprise concrete aggregates--and it also includes problems not related to aggregates. By an interesting coincidence, I am also scheduled to participate next month at the ACI Convention in Philadelphia in the Symposium on Cracking of Concrete, for which the subject that has been assigned to me is "Cracking Induced by

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* [illegible] par[illegible] at the request of Mr. Delmar L. Bloem, Director of Engineering, [illegible] presentation at the Joint Engineering Session of the Annual Conventions [illegible] the National Sand and Gravel Association and the National Ready-Mixed Concrete Association, Chicago, Illinois, 10 February 1966.

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Environmental Effects." There is a sense in which my remarks here today are chapter 1 and those I will make in Philadelphia are chapter 2 of a continued story. I hope that most of you will be at the ACI meeting, for reasons other than hearing chapter 2 of my story, and, more importantly, I hope that what I say today will not keep any of you away from Philadelphia.

There is no variety of concrete, nor indeed any other substance, either natural or man-made, that is unchanging or everlasting. In the real world all substances alter with time and exposure, no matter how mild the exposure may be. The only approach to effective freedom from change over time for materials is to select the most inert available materials, such as pure gold or pure platinum, and store them at constant temperature in a vacuum. Thus, for a substance such as concrete, when one talks of freedom from deterioration, one necessarily talks not in an absolute sense but in a relative sense. Specifically, it is not necessary to avoid all change however minor for an infinite time, but it is only necessary to avoid changes of a nature and degree so as to impair the ability of the concrete properly to serve its intended purpose for a period of time appropriate to the intended service life of the structure of which it is a part.

It is thus suggested immediately that different structures have different intended service lives--in military operations the service life may be days or weeks; structures at a World's Fair may need to remain serviceable for two or three years; a dam or a sea wall may, in some cases, be expected to endure indefinitely. It is also immediately suggested that changes that impair the ability of concrete in one structure to serve its intended purpose would not necessarily impair that in another structure to such a degree. Surface defects

produced by changes after construction on a surface with regard to which there was no requirement for smoothness or aesthetic quality during construction may be of no concern; similar defects on an architectural concrete facade may render it unserviceable unless repaired. Cracks in a paved path in a park may actually add a desired rustic effect--similar cracks in a tank might render the tank useless.

I assume, therefore, that we can agree that: (a) neither complete absence of change nor infinite durability are desired of concrete in service, and (b) differing requirements for allowable degrees of change over differing periods of needed service free of excessive change are applicable to concretes in differing structures. From this it follows that, if it were more costly to produce concrete with confidence that it would serve with lesser change or for a longer period before manifesting a given degree of change, it would also follow that the requirements for concrete--concrete materials and concrete construction practices--should vary widely. More restrictive provisions should be invoked the lesser the allowable changes or the longer the required period of freedom from a given degree of change--or both. Only if concrete were a material that was always and inevitably the same--as is pure gold--then there would be no reason to raise any such questions. The only questions that would be appropriate under these conditions would be: (1) Will gold serve the purpose? and (2) Is it the most economical available material? If both questions are answered yes--use gold; if not, don't.

But, as we all know, concrete is not a single uniform material that always and inevitably possesses the same properties and undergoes identical changes at identical rates in a given environment. Thus it is appropriate to consider

different concretes for different required degrees of freedom from change and different periods of service without such specified degree of change.

There is the additional factor, which for our purpose is perhaps the major complicating factor, namely, the difference in the environment from place to place where concrete must manifest the desired freedom from change for the desired period of time. For our purposes I will include under the heading of the environment, as it affects the ability of a concrete to serve its intended purpose satisfactorily, not only those obvious environmental factors such as weather or climate that affect temperature extremes and rates of temperature change, freezing and thawing, wetting and drying, but also factors such as attack on concrete by natural or man made agents or agencies, both chemical and physical, including acids, salts, sulfates, air-borne corrosive gases, termites, marine borers, and so on, that can induce undesirable changes.

At this point I hope I have suggested, in a more or less logical and orderly manner, a conclusion that everybody knows already and which can be stated in many different ways, some of which are as follows:

a. No two concretes are alike, indeed no two points in a given concrete are alike.

b. No two structures have precisely identical requirements for the concrete of which they should be composed; indeed no two points in a given structure have the same requirements, since the environment will not be precisely the same at two different points.

c. No one concrete should be expected to behave exactly the same way in two different places, or even at two different points in the same structure.

Since it is my intention and my desire in making these remarks to be useful, and practical, rather than confusing or impractical; now that I have indicated the complexity of the situation with which concrete, and those who make it and those who design, build, and use structures composed wholly or in part of it, are confronted; I will try to suggest how these complexities can be dealt with and their potentially undesirable consequences can be avoided.

There are only two ways in which it can develop that the concrete at a point in a structure has failed to maintain a satisfactory degree of freedom from change for a satisfactory period of time: either (a) the specifications under which it was built were not complied with or (b) the specifications were defective in failing to include one or more requirements that should have been included.

Failure to comply with the requirements of specifications is breach of contract, and remedial action following such failure should be taken by those concerned with legal and fiscal matters. The tendency for such failure to occur, however, is greatly increased by the inclusion in specifications of ambiguous, redundant, unnecessary, impractical, or impossible provisions. Ideally the contractor should obtain appropriate positive official clarification of all ambiguities and removal of all redundant, unnecessary, and impossible provisions before he is confronted with the point in the work to which they apply. In practice, too often, this is not done, and such provisions are merely ignored. On such a job the likelihood is that some other provision, one which must be complied with if the intended service is to be obtained, will also be ignored through failure to appreciate its significance.

Failure of the specifications to include all of the requirements that must be met, if the concrete is to give the desired service, results either from lack of knowledge concerning what should be required or from failure to use properly the available knowledge. It has recently been stated[1] that "if half the available knowledge on concrete was put into practice, 95 percent of the problems would evaporate." Lack of knowledge results from the failure of research to have been carried out to produce the needed knowledge. This, in turn, results primarily from failure of government and industry adequately to support the research that needs to be done. Lack of knowledge, especially in the field of construction practice, is also significantly contributed to by failure of those having such knowledge to record and publish it. Knowledge that has not been disseminated through publication is knowledge that is unavailable for use by others.

Failure to use available knowledge results from failure of specification writers to read, understand, and apply the information and conclusions given in the literature that is available. This failure is contributed to, at least to some extent, by the failure of some writers to include with the report of their findings the sort of discussion and interpretion of these findings that will facilitate the application of the findings to specification requirements.

We may then conclude that, while there are an infinite number of varieties of concrete and an infinite range of requirements that concrete must meet, the concrete in any given point in a structure will remain satisfactorily free from deterioration if the specifications include the necessary requirements and are complied with. I have also suggested that greater assurance

of compliance with necessary requirements of specifications will be promoted by exclusion from specifications of ambiguity and unnecessary, redundant, and impossible requirements.

At this point the question might properly be asked: How many variations on a concrete specification must a specification writer have available to select among in order to have any chance of matching the right one to any particular job? Indeed, it might be asked if I am advocating an infinite number of variations of concrete specifications! My answer is yes, I am advocating an infinite number of different concrete specifications! But I hasten to add, as I hope now to explain, that I do not propose to try to overthrow present practices today or even tomorrow. What I suggest is that the time will come, and I believe sooner than most of us think, when specifications will be assembled by computers. One will feed into the computer a wide range of information concerning all the factors I have mentioned, including the desired service life of the structure or the element of the structure, the kinds and amounts of changes that can be tolerated during the service life; the nature of the climate and the weather; the characteristics of the site; the nature and severity of all other relevant agents and agencies whose attack must be resisted and to what degree; a variety of structural data, including thinness or thickness, orientation, degree of restraint, thickness of cover over steel, ability to drain, and so on; a wide variety of data derived from tests of locally and economically available materials and mixtures; and, if necessary, other data from tests of more exotic, less economical materials and mixtures; and finally data on construction systems, methods, practices, and schedules. In this manner the truly infinite number of [illegible] concerning combinations of materials and methods can be compared

with the equally truly infinite number of alternatives regarding the service requirements for the concrete and the environment in which these requirements must be met so that the one solution that is most economical can be selected, indicated, and specified. Thus I am suggesting that the concrete specifier should have, in effect, an infinite number of alternative specifications but that only the best one will actually ever need to be assembled for any given job.

If we were today ready to approach the question of preventing undesirable deterioration of concrete by the process outlined above, by specifying only those things that need to be required, all of them, and no more, we would, of course, avoid the troubles that confront us when concrete manifests more deterioration than anticipated during its specified service life. But, if we assume we must continue for a time under procedures of the sort to which we are now accustomed, what improvements can we make? I suggest that the surest guide to success today is simply to learn from experience, preferably the unhappy experience of somebody else. The principal reason why the Corps of Engineers has had no significant trouble with excessive expansion of concrete due to alkali-silica reaction in its flood control and navigation structures in the West is that, as soon as the experience with such expansion by the U. S. Bureau of Reclamation and the California Division of Highways was reported, the investigational program of the Corps of Engineers on the concrete for Civil Works activities was immediately enlarged to develop data and recommendations on how to determine when the danger of such deterioration existed and what requirements should be imposed to prevent its occurrence. Such determinations have been routinely made for many years, and when it is

determined that specific requirements should be included in specifications to provide assurance that deterioration from this cause will be avoided, such requirements are included and are enforced.

The effect of freezing and thawing in producing deterioration of concrete was perhaps the first factor that was recognized by those sent by the Corps of Engineers to make preliminary plans in 1935 to construct a tidal power project near Eastport, Maine. They saw the deterioration that had affected other people's concrete in the area, and they concluded that a concerted effort would be needed if the Corps were to build a major structure there that would manifest no greater changes due to frost action than could be tolerated over its desired service life. Their conclusion has been vindicated in two ways, even though the tidal power project has not been built. The studies started there then have yielded, and are still yielding, both general and specific answers on how to specify concrete that will withstand freezing and thawing. Experience has shown that natural weathering at the mean tide level there is as severe a natural freezing-and-thawing exposure as has been reported anywhere in the world. Much of the information upon which the decision of the Corps of Engineers to require that all concrete in its Civil Works Program that might be exposed to frost action be air entrained, and to do so in advance of similar decisions by any other major specifying agency, was derived from tests conducted there, based ultimately on observing deterioration due to freezing and thawing of other people's concrete.

All concrete changes with the passage of time. Concrete deterioration is not a matter of concern unless the changes that are described as "deterioration" are changes of a greater degree or a different type than were anticipated

was expected and therefore would have been tolerated in the time during which the concrete had been in service. Changes of undesirable types or of an undesirable degree can be prevented by including in the construction specifications those provisions which, if complied with, will cause the concrete satisfactorily to resist the forces of change to an adequate degree for an appropriate period of time; and by insuring that these provisions are complied with. The best way, today, to insure that the specifications for any given concrete contain the necessary provisions is to appreciate the factors that have been responsible for previous deterioration of other people's concrete and to include provisions in your specification that will preclude deterioration for that cause in your concrete. Ultimately, as more precise quantitative knowledge of the relationship of concrete properties and properties of the environment becomes available, precise specifications can be assembled that properly match service conditions and concrete properties to provide the most economical concrete that can be guaranteed to give the desired freedom from deterioration in the service environment.

References

(1) McLaughlin, John F., "View from the ivory tower." Concrete Products, vol. 68, No. 12, December 1965, p 24.

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